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VOICE WARNING SYSTEMS – A COCKPIT IMPROVEMENT THAT SHOULD NOT BE OVERLOOKED

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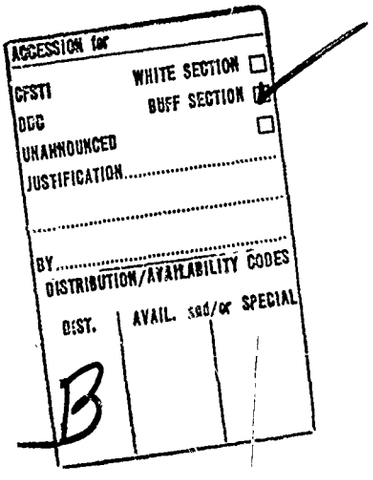

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13 ABSTRACT

Today's pilot receives an overwhelmingly large number of audio and visual signals. Under high stress and task load conditions, such as in combat, the audio-visual load on the pilot may reach saturation levels causing performance to decline. A voice warning system (VWS) with combat mode blocking of unnecessary messages may reduce the audio load to the pilot. Further, a VWS provides the pilot the option of responding to or ignoring a failure based on mission requirements. This is an important advantage with the advent of "head out" flying. VWS improves both mission performance and flight safety and should be seriously considered for installation on future aircraft.

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FOREWORD

This report was prepared by the Controls and Displays Branch, Human Engineering Division, 6570th Aerospace Medical Research Laboratory of the Aerospace Medical Division. The investigation was conducted under Project 7184, "Human Performance in Advanced Systems," Task 718410, "Criteria for the Design and Arrangement of Controls and Displays". The author wishes to express his sincere appreciation to Major Paul Kemmerling, Personnel Subsystems Branch of the Aeronautical Systems Division, for releasing data and other information upon which this report was in part based. Thanks are also due to Lt Col Richard L. Ravenelle and Dr. Melvin J. Warrick for their review and comments.

This technical report has been reviewed and is approved.

CLINTON L. HOLT, Colonel, USAF, MC
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VOICE WARNING SYSTEMS —

A Cockpit Improvement That Should Not Be Overlooked

Pilots flying today's sophisticated high performance fighter aircraft are exposed to a myriad of audio and visual signals. In combat, and under other high stress conditions, the audio-visual load on the pilot may reach saturation level potentially causing efficiency and performance to decline. One way of improving pilot performance in a signal saturated cockpit environment is to provide more information per message and allow the transmission of only absolutely essential messages. A warning system using recorded voice messages as a means of signaling aircraft status and incorporating combat mode blocking of unnecessary messages meets these criteria. Such a voice warning system (VWS) should improve pilot performance under high task loading and thus increase aircraft safety.

Voice warning systems have been an operational possibility for signaling aircraft status at least since 1958.[1] However, while interest by industrial and military research planners has increased, there has been a marked reluctance on the part of some operational elements to accept the voice warning system concept. Resistance to change and overriding priorities in the aircraft acquisition phase have been important factors in impeding the acceptance of voice warning systems.

The Air Force's interest in VWS accelerated in 1961 when the decision was made to equip the entire B-58 fleet with a Voice Interruption Priority System (VIPS) on an experimental basis. The response to the new system was

[1] Voice Warning Systems for Aircraft, Unpublished Nortronics report, 1968.

extremely favorable. Out of 97 experienced B-58 pilots who, in 1967, responded to a questionnaire prepared by the Office of Directorate of Aerospace Safety, all but six felt that the Voice Warning System contributed to flight safety in the B-58. Further, all but two wanted VWS in the FB-111 if they were assigned to that program.[2]

In 1963, the Tactical Air Command performed a flight test of a voice warning system similar to that used on the B-58 (reference 3). Evaluation of the test results showed that verbal warnings produced significant improvement in pilot reaction time, especially during periods of heavy workload or stress. Although early investigators argued for VWS on the basis of improved reaction time (reference 2, 3), this line of reasoning overlooks the most important advantage of voice warning — it allows the pilot to evaluate the criticality of the situation and the action required without bringing his eye scan back into the cockpit. Improved reaction times to malfunctions is an additional bonus to the more important advantage of allowing the pilot who is flying "heads out" (using a heads up display with eyes looking out of the cockpit) the option of responding to or completely ignoring a failure based on mission requirements. Perhaps early advocates of VWS were ineffectual because their arguments were based almost solely on advantages due to improved reaction times with VWS.

About the same time TAC was performing their study, the Navy performed a flight test of a different voice warning system to determine its suitability as a supplement to existing warning systems in Naval aircraft (reference 4). The Navy found the voice warning systems to be superior to visual warning

[2]Directorate of Aerospace Safety. "Consolidation of B-58 Voice Warning System (VWS) Crew Questionnaire." Norton AFB, California, July 1967.

displays alone, acceptable for service use, and an addition that would contribute to flight safety.

Interest in VWS increased in the Air Force, and SPO's (System Program Offices) for new aircraft evaluated the voice warning concept in an attempt to increase flight safety. In response to queries from both the F-111[3] and C-5[4] SPO's, the Air Force Inspector General for Air Safety (AFIAS) in 1965 stated that its position "...firmly supports the installation of voice warning systems in all high performance aircraft wherein there is not flight engineer position." In arriving at its endorsement, the AFIAS cited several documented incidents where voice warning had been valuable in preventing a serious aircraft mishap.

Although slow to begin development of voice warning systems, the Army in recent years has intensively investigated VWS, primarily for rotary wing aircraft. From studies performed at the Aberdeen Proving Ground, Maryland (reference 5), the Army quickly recognized the advantages of VWS and decided to equip three aircraft systems — the CH-54, the CH-47 and the OV-1 — with voice warning equipment. In March 1970, the flight evaluation of a voice warning system on the OH-58A was completed with favorable results. The Army is currently considering further installations of VWS and is evaluating the merits of synthetically generated voice messages versus recorded voice messages.

[3] Letter dated April 23, 1965 from AFIAS-F3, Deputy Inspector General for Inspection and Safety, USAF to ASD, ASLE-3, Wright Patterson AFB, Ohio. Subject: "F-111 Voice Warning System."

[4] Letter dated October 18, 1966 from AFIDI-MZ, Deputy Inspector General for Inspection and Safety, USAF to SEG, SENY, Wright Patterson AFB, Ohio. Subject: "Request for Information, B-58 Voice Interruption Priority System."

Air forces of other countries are also becoming interested in VWS. The German air force has invested approximately $2,000,000 in the development of an Integrated Status Reporting System and plans to equip its entire F-104 fleet with it. Flight evaluation of the VWS was conducted the first week of June 1970 at the German Test Center, Manching, Germany. The Israeli air force is considering use of a VWS to tell crews when they are approaching maneuvering thresholds likely to induce vertigo. Such a system would free the pilot from other monitoring or combat duties when he is under heavy task loading.

The most recent Air Force laboratory study of VWS was initiated through the Aerospace Medical Research Laboratory and conducted at the Crew Station Simulation Facility in September 1969 (reference 6). Twelve Air Force pilots, current in high performance aircraft, flew a simulated combat bomb sortie under varying task load and auditory saturation levels in an F-111 flight simulator to compare voice and tone warning systems. Pilot scan patterns when receiving a failure were monitored by a hidden camera in conjunction with a video tape unit. From the visual scan pattern, it was found that pilots who receive tone warnings were forced to cross-check the annunciator panel when receiving a noncritical failure. On the other hand, some voice-warned subjects heard the warning and realizing it was a noncritical failure chose to ignore it until a less demanding portion of the mission.

What criticisms of VWS are usually made by its opponents? Early voice warning systems were criticized as too costly, too heavy, too big, and too unreliable. Hardware improvements on VWS have made these criticisms invalid. There are now available production model VWS's with a mean-time-between-failures (MTBF) of greater than 10,000 hours, a total weight of less than

four pounds and a total size of less than 45 cubic inches.[5]

Critics with operational experience often fear that VWS will interfere with other audio transmissions. With the development of an override option and combat mode blocking, VWS may actually reduce the audio load of the pilot. The override option allows the pilot to silence a message after hearing it once by pressing an OVERRIDE button on the control panel. This override acknowledgement of the message will silence the system unless there is another warning message to be acknowledged or another higher priority message occurs after the override action. Combat mode blocking allows only crucial warning messages (i.e., ENGINE FIRE) to be given during critical portions of the mission like the final phase of bomb run or in air-to-air combat. The override option together with the combat mode blocking of less crucial signals will, in all likelihood, result in a net reduction of audio transmissions to the pilot.

Early warning systems were criticized for being unable to handle multiple failures. However, today's third generation VWS have a priority sequence of failures. If two failures occur simultaneously, a warning is first given about the higher priority failure. When the failure is corrected or acknowledged by pressing the override button, a warning about the second lower priority failure is given. The priority system can also be constructed in such a way as to signal two failures which occur simultaneously as a failure of higher priority than either failure alone. Of course, for each particular aircraft a priority system would have to be established according to the mission and special characteristics of the aircraft and its auxiliary equipment.

[5] ACI Speech Synthesis Programs, Unpublished Advanced Communications Inc., report, March 1969.

It seems that improvements and refinements of voice warning hardware have dispelled some of the doubts about VWS previously raised by its critics. However, the advantages of VWS are what really make it an attractive cockpit improvement.

As previously mentioned, proponents of voice warning have concentrated mainly on improvement in reaction time to failures with VWS over tone warnings. However, the biggest advantage of VWS is that it affords the pilot the option of responding to or ignoring a malfunction based on mission requirements. If mission requirements are high and the criticality of the failure is low, the pilot may acknowledge the failure by pressing the override button or simply ignoring the warning. In either case, the warning system remains active and if another failure occurs, the pilot will receive a warning about that failure also. When mission requirements permit, the pilot can take the time to correct the failures.

VWS allow the pilot to evaluate and ignore, if necessary, failures without scanning back into the cockpit. VWS cuts out a translation step which is necessary with tone warning signals. With tone warnings, the pilot receives the tone, scans inside the cockpit to the annunciator panel, identifies the signal on the panel, and then responds. With VWS, the pilot goes directly from the voice warning to a reaction, and thus saves time by avoiding a translation step. Tone warning systems merely alert a pilot to a warning, but VWS give the pilot essential information about the warning.

One advantage of having more information per signal is that it reduces the audio load on the pilot. There are approximately 12 proposed tones on the F-15 and there are 40 tones on the F-111. With combat mode blocking capability which allows only very essential warnings during certain high task

loaded portions of a mission, VWS can reduce the number of audio warnings. A good example of the reduction in flight safety with a large number of tones used in the cockpit involves the F-100. To reduce the number of Gear Up landings in the F-100, a tone beeper was installed to warn the pilot if his gear was still up when flying below a certain altitude and airspeed. Gear Up landings were reduced, but the success of the effort caused more beeper tones to be added on the F-100 and other aircraft to warn of other potential problems. As the number of tones increased, the effectiveness of the Gear Up beeper tone decreased and the number of Gear Up landings rose accordingly.

What are some operational situations where the option to respond or not respond without bringing the visual scan back into the cockpit would be valuable? One situation would be in air-to-air combat. When a pilot sees an enemy aircraft he often "padlocks" or keeps his vision on the target. Failure warnings, critical or noncritical, indicated on his instrument panel during such encounters are rarely seen.

When pilots are on the final phase of a bomb or strafe run, or flying number three in a four-ship formation, workload and communication loads are heavy. Flying in such situations is "head out", and a VWS with a combat mode would not only increase "head out" performance and safety but would reduce the number of audio transmissions.

A final operational example is chosen from combat flying experiences in Vietnam. Often F-4's fly night interdiction missions over the Ho Chi Minh trail. Running lights are turned off and cockpit illumination is set low to provide a less conspicuous target to enemy gunners. The pilot then flys along the supply route looking out the window into the darkness for enemy trucks and supply movements. Since a pilot's eyes become accommodated to the dark, it is

very important to be able to keep the visual scan out of the cockpit while searching for and destroying targets on the road.

A further advantage of VWS with combat mode blocking to a pilot flying a combat mission is that only serious failures are given. This cuts out the distraction that warnings of minor failures can produce in a saturated high anxiety portion of the mission. In a high taskload situation the benefits of VWS become most evident by keeping the message simple and keeping the number of messages low.

Voice warning systems may actually produce a weight savings in aircraft by allowing the removal of some tone generation equipment or other warning lights now used on aircraft. The VWS used on each type of aircraft and the resulting tone generator or status lights which could be removed will depend on the particular mission, performance requirements, and other constraints for the aircraft under consideration. One feature of a VWS is that the messages can be as explicit in giving information about correcting, as well as warning of the failure, as required. For new pilots or foreign pilots unfamiliar with the aircraft more explicit instructions may be given. With seasoned pilots in combat a concise warning of the failure is all that should be necessary. VWS provides this flexibility.

The size, weight and message content of the VWS can be fitted to the particular aircraft. However, the VWS should be used to give only important failure information to the pilot; it should not be relegated to the role of an equipment status panel. The pilot should know that only important messages will be generated by the VWS or he will tend to disregard the system as simply another auditory distraction.

Further hardware improvements such as synthetically produced voice warnings and more careful study of multiple-failure priorities and message gating can make the advantages of voice warning more attractive. It is important that the quality of a synthetically generated voice be as good as a tape generated voice message. When the state of the art allows accurate, realistic synthetic voice generation, further weight savings in the voice warning equipment will probably result. However, even with the voice warning equipment available today, single seat fighter aircraft including the F-15 and the AX, should seriously consider installing a VWS. A VWS not only compliments the "head up" displays used on today's aircraft to improve mission performance, but it also contributes to flight safety. A review of recent accident reports in the Air Force shows many situations where voice warning would have been a valuable aid in averting an accident. To quote a recent official accident report,

"During the investigation of an accident involving a high performance fighter aircraft, it was determined that the aircrew channelized their attention due to the sudden and severe onset of the emergency. They were unaware of any warning lights. This is a common finding. It was determined that operational pilots need a stimulus other than warning lights to attract their attention to failures of a priority nature. Recommend that a voice warning system be incorporated into the warning system, with provisions to allow warning of only serious problems in priority sequence and to furnish emergency corrective actions in priority sequence. It is very likely that such a system will prevent accidents by alerting the crew to take corrective actions instead of remaining fixed on certain aspects of the problem in an emergency."[6]

[6]Unclassified TWX from accident investigation panel; dated 13 April 1968.

This accident report and others have induced the Inspector General for Air Safety (AFIAS) to strongly recommend that voice warning be included on the new F-15 fighter. Certainly, the advantages of voice warning with regard to mission performance and flight safety make VWS not a fancy extra but an important system which should seriously be considered for installation on present and future aircraft — especially single-seat, high performance fighters.

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